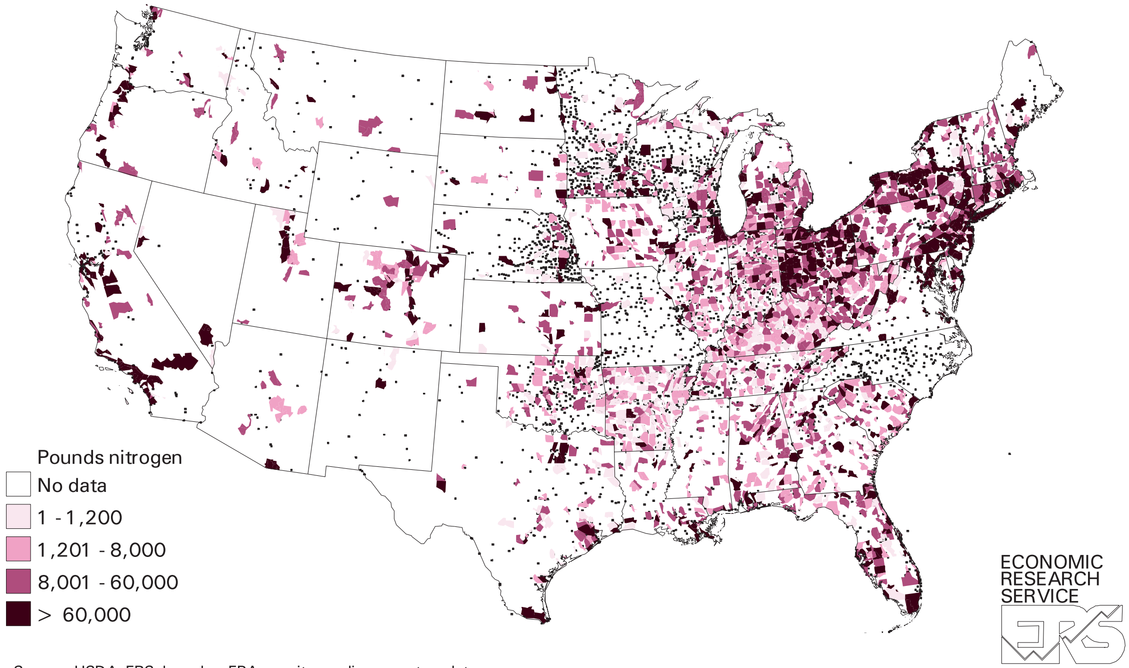
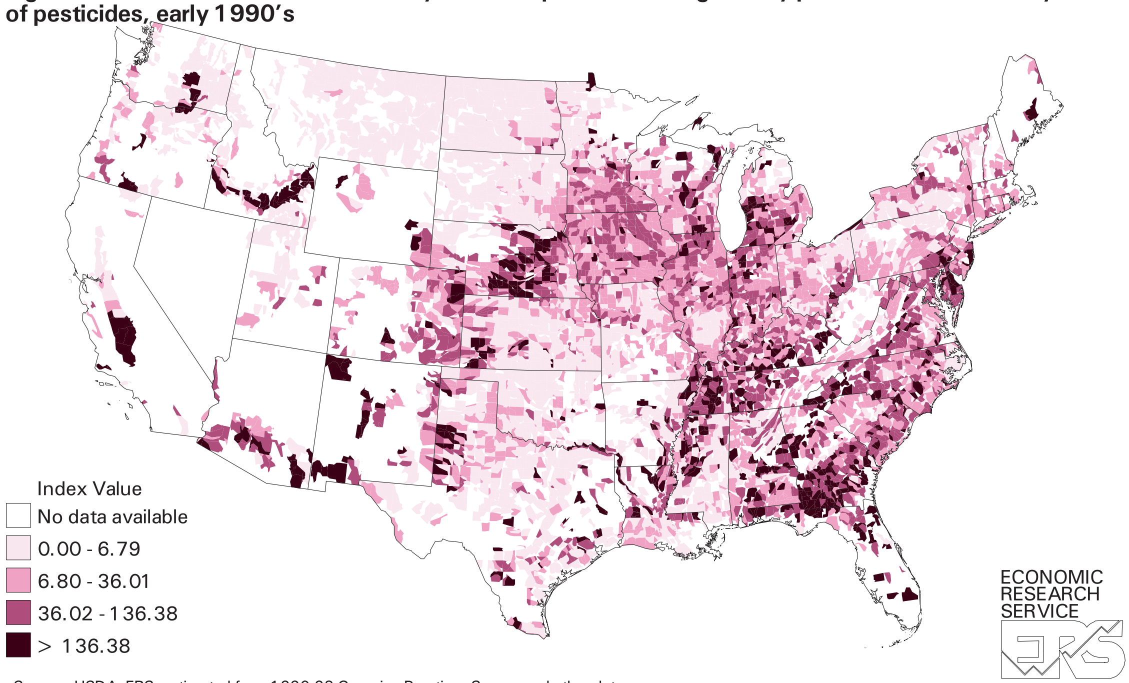
Figure 2.2.3--Nitrogen from point sources (excluding confined animal operations), 1993



Source: USDA, ERS, based on EPA permit compliance system data.

Figure 2.2.4--Groundwater vulnerability index for pesticides weighted by persistence and toxicity of pesticides, early 1990's



Source: USDA, ERS, estimated from 1990-93 Cropping Practices Survey and other data.

Areas with low pesticide use usually have low detection frequencies (Barbash and Resek, 1995). Conversely, areas where a pesticide is detected frequently are often those of high use. However, low frequencies of pesticide detection are often encountered in areas of high use, indicating that other factors influence pesticide movement.

Most studies of pesticides in surface water focus on the midcontinent region where large amounts of pesticides are used. Goolsby and others (1993) found that herbicides are detected at low levels throughout the year in the rivers of the Midwest, including the Mississippi River. The amounts transported by streams and rivers in the Midwest are generally less than 3 percent of the amount applied, but can still result in concentrations above the MCL. Atrazine (and its metabolites), alachlor, cyanazine, and metolachlor, used principally for weed control in corn and soybeans, were the principal contaminants detected, and are also the most widely used pesticides in the region. Such chemicals, once in drinking water supplies, are not controlled by conventional treatment technologies (Miltner and others, 1989). About 21 million people in the Midwest rely on drinking water from surface sources, about 42 percent of the population.

High concentrations of atrazine in some water supplies in the Midwest have prompted concerns that public water utilities will have to install expensive water treatment systems in order to meet Safe Drinking Water Act requirements. In 1990, about 29 percent of public utilities dumped powdered activated carbon into their systems to spot-treat for organic chemicals, primarily pesticides (American Water Works Association, 1992). If all the treatment plants withdrawing from surface sources upgrade their treatment systems to remove pesticides, annual treatment costs would increase by $400 million per year (Ribaudo and Bouzaher, 1994). Because of these concerns, EPA has placed the triazine herbicides (atrazine, cyanazine, and simazine) under special review due to potential health and ecological concerns. DuPont has already announced that it will phase out its cyanazine production.

Some pesticides leach into underlying aquifers. EPA's survey of drinking water wells found that 10 percent of the CWS's and 4 percent of rural domestic wells contained at least one pesticide (1990). Pesticides or their transformation products have been detected in the ground waters of 43 States (Barbash and Resek, 1995). However, the EPA estimated that less than 1 percent of the CWS's and rural domestic wells had concentrations above MCL's or Lifetime Health Advisory Levels (the maximum concentration of a water contaminant that may be consumed safely over an average lifetime). Problems were found more frequently in shallow wells in agricultural areas. A sampling of wells in corn- and soybean-growing areas in the Midwest found 28 percent of wells had detectable levels of selected pesticides and metabolites, but none exceeded the MCL (Kolpin, Burkart, and Thurman, 1993). Atrazine was the most frequently detected compound.

Groundwater vulnerability to pesticides varies geographically, depending on soil characteristics, pesticide application rates, and the persistence and toxicity of the pesticides used (fig. 2.2.4) (see chapter 3.2, *Pesticides*, for more discussion of persistence and toxicity). Areas with sandy, highly leachable soils, such as central Nebraska and the blueberry barrens of Maine, have high vulnerability ratings. Highly vulnerable areas characterized by heavy applications of generally toxic materials on fruit and vegetable crops include the San Joaquin Valley in California, Florida, and southern Arizona. In contrast, the Corn Belt, despite the widespread use of chemicals, particularly herbicides, has a lower rating than other areas because the predominant soils are not prone to leaching.

Animal Waste

Animal operations can generate large amounts of waste which, if improperly handled or disposed of, can affect the quality of surface- and groundwater resources. Improperly constructed storage pits or lagoons at confined facilities can break or leak, releasing large amounts of concentrated waste directly into surface water. Dissolved material can leach into groundwater if lagoons or pits are improperly lined. Pastured animals allowed to graze near or to water in streams can contaminate water. Improper application of animal waste on fields, such as spreading on frozen ground, can result in large amounts being flushed into water bodies after rain or a thaw.

An issue of increasing importance to water quality is the management of manure from confined animal operations. This stems from increasing concentration in the animal industry, a number of incidents where manure has contaminated local water bodies (see box "Animal Waste Storage Failures"), and a greater awareness of the potential for contamination of drinking water supplies by waste-borne parasites. Larger operations, particularly for hogs and dairy cows, now characterize the industry. As animal production units grow increasingly large and

Animal Waste Storage Failures

The growing concerns over concentrated animal operations were highlighted when a dike around a large hog-waste lagoon in North Carolina failed, releasing an estimated 25 million gallons of hog waste (twice the volume of the oil spilled by the Exxon Valdez) into nearby fields, streams, and the New River. The 8-acre earthen lagoon was built to allow microbes to digest the waste, and is a common form of management for confined operations. The spill killed virtually all aquatic life in the 17-mile stretch between Richlands and Jacksonville, NC.

There are approximately 6,000 confined animal operations with at least 1,000 animal units in the United States. (One animal unit equals 1 beef animal, 0.7 dairy cow, 2.5 hogs, 18 turkeys, or 100 chickens.) Under the Clean Water Act, these facilities cannot discharge to waters except in the event of a 25-year/24-hour storm. This requirement necessitates the construction of onsite storage facilities for holding manure and runoff. In addition to these large operations, facilities with more than 300 animal units that discharge directly to waters are required to take the same measures. Regions with large numbers of animal operations containing more than 1,000 animal units include the Northern Plains (for beef), Pacific (dairy), Corn Belt (swine), Appalachian (swine), and Southeast (broilers).

Most States are responsible for carrying out Clean Water Act regulations. A survey of livestock waste control programs in 10 Midwest and Western States indicated that few States actively inspect facilities for problems, including the integrity of storage structures (Iowa Dept. Nat. Res., 1990). National estimates of broken or leaking storage facilities do not exist. However, a North Carolina State University study estimated that wastes were leaking from half of North Carolina's lagoons built before 1993 (Satchell, 1996), so the problem may be widespread.

specialized, they tend to lack sufficient cropland on which manure can be spread. Without adequate cropland, larger and more sophisticated manure handling and storage systems are required. Improper management, equipment failure, or unusual rainstorms can cause serious water quality problems.

Animal waste contains a number of pollutants. Waste can contain significant amounts of nitrogen and phosphorus. These nutrients pose the same concerns about eutrophication and methemoglobinemia as inorganic sources. In addition, fish and other aquatic organisms may die from ammonia produced as manure decays, or they may suffocate due to insufficient oxygen levels caused by the oxygen-demanding decomposition of organic matter in the manure.

Nitrogen from animal waste is an important source of total nitrogen loads in some parts of the country. Many areas have high ratios of nitrogen from manure on confined animal operations to the operations' land available for spreading (see chapter 4.5, *Nutrient Management*). The highest ratios of nitrogen to land are found in parts of the Southeast, Delta, and Southwest. Studies in 16 watersheds found that manure was the largest nitrogen source in 6, primarily in the Southeast and Mid-Atlantic States (Puckett, 1994).

Animal waste also contains pathogens that pose a threat to human health. Up to 150 diseases from the microorganisms in livestock waste can be contracted through direct contact with contaminated water, consumption of contaminated drinking water, or consumption of contaminated shellfish. Some illnesses that can be contracted from animal waste include cholera, tuberculosis, typhoid fever, salmonella, and polio. Parasites of concern include cryptosporidium and giardia.

Outbreaks of cryptosporidia, a parasite found in the feces of some animals and that causes gastrointestinal illness, are causing growing concern over the safety of water supplies in areas with large numbers of cattle. This organism has been implicated in gastroenteritis outbreaks in Milwaukee, Wisconsin (400,000 cases and 100 deaths in 1993) and in Carrollton, Georgia (13,000 cases in 1987). The cost of the Milwaukee outbreak is estimated to exceed $54 million (*Health and Environment Digest*, 1994). While the source of the organism in these outbreaks was never determined, its incidence in many dairy herds has brought some attention to this sector, especially given the proximity of dairies to population centers.

Salinity

Irrigation return flows can carry dissolved salts, as well as nutrients and pesticides, into surface- or groundwater. Dissolved salts and other minerals can have significant impacts on surface- and groundwater quality. Increased concentrations of naturally occurring toxic minerals, such as selenium and boron, can harm aquatic wildlife and degrade recreation opportunities. Increased levels of dissolved solids in public drinking water supplies can increase water treatment costs, force the development of alternative water supplies, and reduce the lifespans of water-using household appliances. Increased salinity levels in irrigation water can reduce crop yields or damage soils so that some crops can no longer be grown.

Dissolved salts and other minerals are an important cause of pollution in the Southern Plains, arid Southwest, and southern California. Total damages from salinity in the Colorado River range from $310 million to $831 million annually, based on the 1976-85 average levels of river salinity. These include damages to agriculture ($113-$122 million), households ($156-$638 million), utilities ($32 million), and industry ($6-$15 million) (Lohman, Milliken, and Dorn, 1988).

The USGS reports mixed trends of salinity in surface water (Smith, Alexander, and Lanfear, 1993). Measures of dissolved solids (mostly ions of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride) indicate that water quality improved at more stations than it worsened. However, while salinity trends in water for domestic and industrial purposes generally improved during the 1980's, salinity worsened for irrigation purposes. Among USGS cataloguing units (watersheds) having significant irrigation surface-water withdrawals, the percentage of stations having annual average dissolved solids concentrations greater than 500 mg/L increased during 1980-89 from 30 to 33 percent.

Reducing Loadings from Agriculture

Farmers can take many steps to reduce loadings of agricultural pollutants to water resources. Both structural and management practices are available to farmers. In a study of 16 of USDA's 242 Water Quality Program projects, 134 different practices were installed, nearly half of which were labeled "new and innovative" (USDA, NRCS, 1996). Water quality practices work by managing water and chemical inputs more efficiently, or by controlling runoff. Practices include pest management, nutrient management, irrigation water management, animal waste management, tillage management, and runoff control (for more on practices, see chapters 4.1-4.6).

Groundwater Vulnerability Indexes

The groundwater vulnerability index for nitrates (GWVIN) was developed by Kellogg and others (1992). It is a function of soil leaching potential, nitrate leaching potential, precipitation, and nitrogen fertilizer use. Excess nitrogen per acre is the difference between the amount of nitrogen from commercial fertilizer and animal manure applied, including credit for nitrogen fixed by previous leguminous crops, and the amount taken up by the crop.

The groundwater vulnerability index for pesticides (GWVIP), also developed by Kellogg and others (1992), is a function of soil leaching potential, pesticide leaching potential, precipitation, and chemical use. It is an extension of the national-level Soil-Pesticide Interaction Screening Procedure (SPISP) developed by the Natural Resources Conservation Service (Goss and Wauchope, 1990). GWVIP does not depend on the amount of chemical applied, but the type of chemical, its leaching potential, and the leaching potential of the soil to which the chemical is applied. The GWVIP can be weighted by persistence and toxicity to further account for potential harm to the environment. Persistence is defined as the soil half-life. Toxicity is defined as the acute oral toxicity to rats. Chronic toxicity or toxicity to fish would have been preferred, but these data are not available for most pesticides. For further discussion of weighting for persistence and toxicity, see chapter 3.2, *Pesticides*.

USDA has had several programs that provide farmers the means to adopt water quality practices, including the Agricultural Conservation Program, Water Quality Incentive Projects, and the Water Quality Program. Most current programs focus on providing education, technical, and financial assistance to farmers to get them to adopt alternative management systems that protect water quality. Education raises farmer awareness not only of the potential financial and environmental benefits of alternative practices, but also of the link between the practices they implement and local water quality. Technical and financial assistance provide the means for a farmer to actually try a new practice and to acquire the skill to apply it effectively. Failure of voluntary programs to achieve needed changes in farming practices may increasingly result in regulations, already occurring in a number of States (see chapter 6.2, *Water Quality Programs*, for more on Federal and State programs).

Improvements in water quality from farmers' efforts to reduce pollutant loadings often take years to detect and document. The links between improved management and observed changes in water quality are complex. As many as 10 consecutive years of water quality data are needed before long-term changes can be distinguished from short-term fluctuations (Smith, Alexander, and Lanfear, 1993). Phosphorus accumulated in bottom sediments will affect water quality long after conservation practices have dramatically reduced phosphorus loadings in runoff. Similarly, fish, insects, and other biological indicators of a healthy stream may not reach acceptable levels until many years after water quality improves and riparian habitat is restored. Aquifers may take decades to show improvements in quality after chemical management is improved. In most project areas, agriculture is not the only source of pollution.

In addition, many projects do not establish or maintain adequate water quality monitoring for detecting changes in water quality. National water quality monitoring systems already in place are inadequate for detecting changes in small watersheds where water quality programs have generally been targeted. For these reasons, improvements in water quality may in fact be taking place undetected.

Costs and Benefits of Pollution Control

The assessment of policies to reduce pollution from agricultural production requires a complete knowledge of benefits and costs to water users of changes in water quality. Benefits and costs are measured in terms of changes in economic welfare, represented by consumer and producer surpluses. Estimating the economic effects of changes in water quality is complicated by the lack of organized markets for environmental quality. There are no observed prices with which to measure economic value. A number of methods exist for deriving these measures. One method for estimating consumer surplus is to study an individual's behavior in averting the consequences of poor environmental quality, such as expenditures made to prevent household damages from salinity. A second approach is to exploit the relationship between private goods and environmental quality (when it exists) to draw inferences about the demand for environmental quality. A third approach is to ask individuals to reveal directly their willingness to pay for changes in environmental quality.

When water quality is a factor in the production of a market good, the benefits of changes in quality can be inferred from changes in variables associated with the production of the market good. There are two avenues through which benefits can be obtained. The first is through changes in the price of the marketable good to consumers. The second is through changes in incomes received by owners of factor inputs. The choice of approaches for estimating consumer and produce welfare effects depends largely on the availability of data and the nature of demand for water quality.

Economists have conducted numerous studies of the value of water quality over the years. Most of these studies have focused on specific sites or "local" water quality issues (Crutchfield, Feather, and Hellerstein, 1995). Relatively few studies have looked at the costs of water pollution and the benefits of pollution reduction on a nationwide scale, and none have included costs to all classes of water users (table 2.2.3). However, the results of these studies indicate that the annual benefits from improving water quality could total tens of billions of dollars. Water quality benefits from erosion control on cropland alone could total over $4 billion per year (Hrubovcak, LeBlanc, and Eakin, 1995).

Although increasing, public funds spent on nonpoint source pollution are small compared with the expenditures on point sources. Between $80 and $100 billion of public funding was spent on water pollution control during the 1980's (Ervin, 1995), mainly to control pollutants from municipal sources. In contrast, only $1 to $2 billion has been spent on agricultural water quality initiatives over the last two decades (Ervin, 1995). This spending is much less than the potential benefits from improved water quality. However, an increasing amount of financial and other resources is being directed to agricultural nonpoint source pollution. USDA spent $194 million on water quality-related research, education, technical assistance, financial assistance, and data activities in 1995. Such expenditures have doubled since 1989, despite an overall decrease in USDA expenditures for conservation. Farmers themselves have spent an unknown amount on water quality practices, although in many cases changes were made to enhance profitability. In addition, EPA made over $65 million in regional grant awards to States for agricultural nonpoint source programs in 1994-95, an increase of 50 percent over the previous 2-year period. These funds are frequently contracted to cooperating agencies such as local conservation districts to support project implementation. (For more information on water quality programs, see chapter 6.2.)

Table 2.2.3—National estimates of the damages from water pollution or the benefits from water pollution control

Study/year	Estimate of:	Description
Freeman (1982)	National benefits of water pollution control	Total damages to recreational water uses from all forms of pollution: $1.8-$8.7 billion, "best guess" of $4.6 billion (1978 dollars per year).
Russell and Vaughan (1982)	National recreational fishing benefits from controlling water pollution	Total benefits of $300-$966 million, depending on level of pollution control instituted.
Clark et al. (1985)	National water quality damages from soil erosion on cropland	Damages to all uses: $3.2-$13 billion, "best guess" of $6.1 billion (1980 dollars). Cropland’s share of erosion-related damages: $2.2 billion.
Ribaudo (1986)	Regional and national water quality benefits of reducing soil erosion	Erosion reductions from 1983 soil conservation programs implied $340 million in offsite benefits. Benefits per ton of erosion reduced were from $0.28 to $1.50.
Nielsen and Lee (1987)	National costs of groundwater contamination	Monitoring costs for presence of agricultural chemicals put at $890 million-$2.2 billion for private wells, and $14 million for public wells.
Ribaudo (1989)	Regional and national water quality benefits from the Conservation Reserve Program	Reducing erosion via retirement of 40-45 million acres of highly erodible cropland would generate $3.5-$4.5 billion in surface-water quality benefits over the life of the program.
Carson and Mitchell (1993)	National benefits of surface-water pollution control	Annual household willingness to pay for maximum water quality improvement of $205-$279 per household per year, or about $29 billion nationally.
Feather and Heller-stein (1997)	National recreation benefits of soil erosion reductions	A total of $286 million in benefits from erosion reductions on agricultural lands since 1982, based on data from a recreation survey.

Source: USDA, ERS, based on Crutchfield, Feather, and Hellerstein, 1995; and Feather and Hellerstein, 1996.

While regulations were used to reduce point sources, efforts to reduce nonpoint sources have primarily relied on voluntary measures. Analysis has shown that many of the management practices that reduce agricultural nonpoint source pollution are not costly to implement, and may even increase net returns (U.S. Congress, OTA, 1995). A highly targeted approach that emphasizes low-cost land management changes—and that is backed by sound science, technical and financial support, and regulations—would provide the best means of achieving most water quality goals.

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Recent ERS Reports on Water Quality Issues

Accounting for the Environment in Agriculture, TB-1847, October 1995 (James Hrubovcak, Michael LeBlanc, and B. Kelly Eakin). Detailed information derived from the national income and product accounts provides the basis for economic interpretations of changes in the Nation's income and wealth. The effects of soil erosion on agricultural productivity and income, the economic effect of decreased water quality, and depletion of water stock are presented as examples of the potential scope of accounting adjustments needed in the agricultural sector.

USDA's Water Quality Program Enters its 6th Year, AREI Update, 1995, No. 11 (Marc Ribaudo). Sixty-five water quality projects were started in 1995, and 6 projects were completed at the end of 1994. Over 400 water quality projects have been started since 1990.

Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution, AIB-716, May 1995 (Peter Feather and Joe Cooper). Data from the Area Studies are used to evaluate the success of existing incentive programs to control agricultural nonpoint source pollution. Because profitability drives production decisions, these programs tend to be most successful when they promote inexpensive changes in existing practices.

The Benefits of Protecting Rural Water Quality: An Empirical Analysis, AER-701, January 1995 (Stephen R. Crutchfield, Peter M. Feather, and Daniel R. Hellerstein). The use of nonmarket valuation methods to estimate the benefits of protecting or improving rural water quality from agricultural sources of pollution is explored. Two case studies show how these valuation methods can be used to include water-quality benefits estimates in economic analyses of specific policies to prevent or reduce water pollution.

Atrazine: Environmental Characteristics and Economics of Management, AER-699, September 1994 (Marc Ribaudo and Aziz Bouzaher). Atrazine is an important herbicide in the production of corn and other crops in the United States. Recent findings indicate that elevated amounts of atrazine are running off fields and entering surface-water resources. The costs and benefits of an atrazine ban, a ban on pre-plant and pre-emergent applications, and a targeted ban to achieve a surface-water standard are examined.

Cotton Production and Water Quality: Economic and Environmental Effects of Pollution Prevention, AER-664, December 1992 (Stephen Crutchfield, Marc Ribaudo, LeRoy Hansen, and Ricardo Quiroga). The most widespread potential water-quality problems from cotton production are nitrate leaching and losses of pesticides to surface waters. Alternative policies for reducing these types of pollution are evaluated.

Estimating Water Quality Benefits: Theoretical and Methodological Issues, TB-1808, September 1992 (Marc Ribaudo and Daniel Hellerstein). Knowledge of the benefits and costs to water users is required for a complete assessment of policies to create incentives for water quality-improving changes in agricultural production. A number of benefit estimation methods are required to handle the varying nature of water quality effects.

Water Quality Benefits from the Conservation Reserve Program, AER-606, February 1989 (Marc Ribaudo). The Conservation Reserve Program was estimated to generate between $3.5 and $4 billion in water quality benefits if it achieves its original enrollment goal of 40-45 million acres. Potential benefits include lower water treatment costs, lower sediment removal costs, less flood damage, less damage to equipment that uses water, and increased recreational fishing.

(Contact to obtain reports: Marc Ribaudo, (202) 501-8387 [mribaudo@econ.ag.gov])

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